NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1535

A METALLURGICAL INVESTIGATION OF TWO TURBOSUPERCHARGER DISCS OF 19-9DL ALLOY

> By E. E. Reynolds, J. W. Freeman, and A. E. White University of Michigan



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DISCS OF 19-9DL ALLOY

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SUMMARY

Two turbosupercharger discs of 19—9DL alloy were included in a general investigation to determine the properties of this material in forgings of the size actually used in service. The two discs were given hot—cold—working treatments at 1300° to 1350° F. They differed only in that one was solution—treated while the other was left in the as—forged condition prior to hot—cold—working. The contour forgings were made by the Steel Improvement and Forge Company. One—half of each disc was tested by the General Electric Company. The other halves were sent to the University of Michigan for investigation for the NACA.

The small size of the discs limited the number of specimens and the extent of testing. The data obtained by the General Electric Company were therefore included in this report to give a more complete survey of the properties of the discs.

It was found that the rupture strengths at 1200° F were good. There was no appreciable difference in properties between the two forgings; the benefits of hot-cold-work on rupture strengths at 1200° F were not retained at 1350° F; rupture test ductility was very low; the discs had fair uniformity of properties; and the properties compared favorably with those of bar stock. The properties of the solution-treated disc were about average for that type of treatment. The rupture strengths of the as-forged disc at 1200° F were somewhat higher than average for 10 and 100 hours.

INTRODUCTION

Alloy 19—9DL is one of the lower-alloyed materials developed during the war for high-temperature service. The properties of this alloy in various forms have been studied extensively. This report is concerned with the properties of two approximately 12-inch-diameter turbosupercharger discs of this alloy.

The two discs differed in treatment in that one was solution—treated and the other was not. Both discs were hot—cold—worked in contour dies at 1300° to 1350° F. Both were made from the same heat used for a large

gas—turbine rotor forging and bar stock concurrently investigated under NACA sponsorship. The principal object of the investigation was to determine the level of properties developed in these forgings and to show the comparison of these properties with those of the same heat of the alloy in other forms.

One—half of each of the discs was submitted for study at the University of Michigan for the NACA. The other halves were tested by the General Electric Company and their data are included in this report to give a more complete property survey. Through the courtesy of the General Electric Company Mr. W. L. Badger of their Thomson Laboratory furnished comparative rupture strengths for 15 other turbosupercharger discs. The work at the University was limited to rupture tests at 1200° and 1350° F and two creep tests at 1200° F on each disc. The investigation was conducted at the University of Michigan under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics. It constitutes one phase of a research program, sponsored at the University by the NACA, on the metallurgy of heat—resisting alloys used in gas turbines for aircraft propulsion systems.

TEST MATERIAL

The available information concerning the two turbosupercharger discs, ZD1952 and ZD1957, of 19-9DL alloy is summarized as follows:

Steel producer:

The Universal—Cyclops Steel Corporation, Bridgeville, Pennsylvania Disc manufacturer:

The Steel Improvement and Forge Company, Cleveland, Ohio Chemical composition:

Both discs were produced from heat B10429. The chemical composition was reported to be the following percentages:

C Mn Si P S Cr Ni Mo W Cb Ti

0.33 1.14 0.65 0.016 0.015 19.10 9.05 1.35 1.14 0.35 0.16

Fabrication procedure:

The following information, concerned with fabrication of the two discs, was supplied by the Universal-Cyclops Steel Corporation and the General Electric Company. Both discs were fabricated the same

way with the exception of the solution treatment given disc ZD1957 listed in item (3) below:

- (1) Billets were obtained from a 10,000-pound arc-furnace heat
- (2) Approximately 12-inch-diameter turbosupercharger discs were forged from the billets
- (3) Heat treatment:
 Disc ZD1952: None
 Disc ZD1957: Heated at 2100° F for 1 hour and air—cooled
- (4) Both discs were hot-cold-worked at 1300° to 1350° F in closed contour dies
- (5) Both discs were stress-relief annealed at 1200° F for 4 hours and air-cooled

The shape of the contour forgings is shown in figures 1, 2, and 3.

EXPERIMENTAL PROCEDURE

The half sections of the two turbosupercharger discs supplied to the University of Michigan were intended to be used for rupture and creep tests at 1200° and 1350° F to time periods of 2000 hours. The following testing program was used:

- (1) Rupture tests at 1200° and 1350° F
- (2) Creep tests at 1200° F under stresses of 15,000 and 20,000 psi
- (3) Metallographic, tensile, and hardness tests when possible to determine stability characteristics of the material

The necessary test specimens were machined from coupons cut from the forgings according to figure 1. Included in this figure is the sectioning diagram for the halves of the discs tested by the General Electric Company. Locations of the General Electric Company tensile specimens are shown in figures 2 and 3. Creep tests were conducted on 0.400—inch—diameter specimens with a 2—inch gage length. The specimens for rupture tests were 0.160—inch diameter with a 1—inch gage length.

RESULTS

The small size of the discs limited the number of specimens and the extent of testing. For this reason General Electric Company tensile, hardness, and rupture data for the two discs have been included in this

report to supplement the rupture and creep data obtained at the University. The data are presented as a series of tables and figures which show the rupture, time-deformation, creep, stability, hardness, and tensile characteristics.

Rupture Test Characteristics

The rupture test data at 1200° and 1350° F are given in table I. The usual double-logarithmic curves of stress against rupture time are shown in figure 4. Rupture strengths and estimated ductilities to fracture are included in table I.

There was no appreciable difference in rupture strength between the two forgings at either temperature. At 1200° F strengths for rupture in 100 and 1000 hours were 52,000 and 37,000 psi, respectively. Corresponding strengths at 1350° F were 24,000 and 13,000 psi. The ductility to fracture was very low for both discs, ranging from 1 to 3 percent elongation at both 1200° and 1350° F.

Time-Deformation Characteristics

This type of information is limited to results from two creep tests and several low-deformation rupture tests at 1200° F. The available time-deformation data are given in table II and plotted to coordinates of stress against the logarithm of time in figure 5. These data were obtained from the curves of time against elongation from the creep tests and rupture tests. From the limited data it was estimated that the two discs had the same time-deformation strengths. These are given in table III. Figure 5 and table III include comparative data for the large forged gas-turbine disc made from the same heat, Bl0429. (See reference 1.) The hot-cold-worked turbosupercharger discs had substantially higher deformation resistance at total deformations above 0.1 percent than the large forged disc.

Creep Strengths

Creep rates for the creep and rupture tests at 1200° F are given in table II. The creep rates from the creep tests are those at 1000 hours. It appeared from the creep test of 2000-hour duration at 20,000 psi on disc ZD1952 that the 1000-hour creep rates were probably higher than the minimum rates which would have been obtained if the tests had been continued for longer time periods.

Creep rates are plotted against stress on double-logarithmic coordinates in figure 6. Because of the very limited amount of creep test data obtained for the turbosupercharger discs, the curve of stress against creep rate for the large forged turbine disc of 19-9DL is drawn on this figure and the points for the turbosupercharger discs compared

with this curve. The creep strengths of the turbosupercharger discs were estimated to be approximately equal and were the same as those for the large disc. These strengths were 25,000 psi to produce a creep rate of 0.0001 percent per hour and 11,000 psi for a rate of 0.00001 percent per hour.

Stability Characteristics

After creep testing at 1200° F, the room-temperature tensile properties of a specimen from disc ZD1952 were substantially the same as those of the original material. (See table IV.) There was a decrease in hardness during rupture testing of both discs, this decrease being quite appreciable at 1350° F.

The microstructures of the original material and of specimens after completion of rupture tests are shown in figures 7, 8, and 9. The original microstructure indicated that there was more fine precipitated phase present in disc ZD1957, which was solution—treated prior to hot—cold—work, than in disc ZD1952. A considerable variation in grain size within each disc is indicated by the difference in grain sizes of the 1200° F rupture specimens and the samples used for the original structures.

Rupture testing at 1200° F did not change the structure noticeably. There was considerable precipitation and agglomeration of excess constituents during testing at 1350° F which, with the accompanying hardness decrease, indicate structural instability in the material.

Data from the General Electric Company Laboratory

Half sections of each of the two turbosupercharger discs were examined by the General Electric Company for tensile properties at room temperature, 1200°, and 1500° F, hardness at room temperature, and rupture characteristics at 1200° F. Tensile and hardness data are given in figures 2 and 3. The rupture test data are plotted in figure 4 with the University of Michigan results. (See reference 2.)

The Brinell hardness tended to be higher near the rim than near the center of each disc. No apparent difference in hardness existed between the discs. The discs had similar tensile properties. There was a slight tendency for the material from near the center to be weaker than material from near the rim. The ductility tended to be less at 1200° F than at room temperature or at 1500° F.

DISCUSSION OF RESULTS

There were no appreciable differences observed in any of the properties of the two turbosupercharger discs of 19-9DL alloy. The solution

treatment prior to hot—cold—work on the one disc is therefore considered to have had no appreciable effect on the properties studied. It should be recognized, however, that the forging conditions could have been equivalent to an effective solution treatment if the finishing temperature had been high. The solution treatment on disc ZD1957 would have had little effect under this condition and would not have appreciably changed its structure from that of disc ZD1952 which probably was effectively solution—treated during forging.

An unusual opportunity to determine how well the two discs covered by this investigation represent the properties of average production of such discs is provided by the data in table V. The General Electric Company furnished the rupture strengths at 1200° F used in this table for 15 other discs. The solution—treated and hot—cold—worked disc ZD1957 had properties quite close to the average for discs treated in that manner. Somewhat higher properties than average were exhibited by the forged and hot—cold—worked disc ZD1952.

The data in table V indicate that solution—treating prior to hot—cold—work does have the advantage of improving rupture strength at 10 and 100 hours at 1200° F. The forged and aged discs were somewhat stronger at 1000 hours. Both types of treatment, however, result in a spread in properties between different discs. The data for disc ZD2273 also illustrate the possibility of an occasional disc of very low strength when a solution treatment is omitted.

Heat B10429 of 19-9DL has been tested also as a large forged gasturbine disc and as bar stock. A comparison of tensile and rupture properties for these forms is given in table VI. Included in this table are data for two 20-inch-diameter contour-forged discs of 19-9DL alloy made from another heat.

The two turbosupercharger discs had rupture strength and ductility at 1200° F similar to those of bar stock R19-9DL, which had been hot-cold-worked 20 percent at 1200° F. However, tensile test strength properties were lower than those of hot-cold-worked bar stock. The turbosupercharger discs were superior in tensile and 1200° F rupture strength to the large as-forged turbine disc of the same heat. However, they had much lower rupture test ductility than the large disc.

The turbosupercharger discs had properties quite similar to the large contour disc hot—cold—worked at 1250° F. The contour disc hot—cold—worked at 1650° F had lower strength and higher ductility.

The superiority of hot—cold—worked over as—forged 19—9DL discs in rupture strength at 1200° F diminished with time. The hot—cold—worked material did not exhibit any improvement in ductility with time and in this respect was still quite inferior to the forged or solution—treated material at long time periods. Rupture tests at 1350° F indicated that the improvement in strength properties at 1200° F due to hot—cold—work was not retained at higher temperatures and that the low rupture ductility

was still present. The 100- and 1000-hour rupture strengths at 1350° F for the large as-forged disc were 23,000 and 13,500 psi, which were similar to the strengths for the smaller hot-cold-worked turbosupercharger discs. Corresponding rupture ductilities were 35 and 23 percent as compared with approximately 2 percent for the smaller discs. The structural instability of the small discs at 1350° F, which was similar to that of the larger gas-turbine disc, probably accounts for this equalization of strengths at 1350° F.

The erratic results in the rupture tests at 1200° F shown by both the Michigan and General Electric data (see fig. 4) are probably partially due to variation in sample location and partially to an inherent erratic characteristic associated with the low deformations in the materials. The location of the samples cut from such discs does have considerable influence on the resulting rupture strength. Likewise the erratic test data from specimens from discs may provide somewhat misleading results if sufficient tests are not run to obtain a good average curve of stress against rupture time. The difference in reported rupture strengths for discs ZD1952 and ZD1957 between that indicated by the combined data from two laboratories in figure 4 and the values based on a limited number of tests from one laboratory in table V illustrates the need for complete test data. Both factors may have contributed to the wide spread in rupture strengths indicated by table V as well as actual strength differences between discs.

From the results for these two turbosupercharger discs, it is believed that hot-cold-working such discs develops rupture and time-deformation strengths at 1200° F near the top limit of the range in these properties obtained for 19-9DL alloy as bar stock.

CONCLUSIONS

From a study of the properties at room temperature, 1200°, and 1350° F of two turbosupercharger discs of 19—9DL alloy the following conclusions were made:

- 1. No particular improvement in properties over an as-forged disc was obtained from a solution treatment when subsequent hot-cold-work was used.
- 2. The rupture properties at 1200° F of the disc solution treated before hot—cold—working were probably quite typical of the treatment. The disc hot—cold—worked in the as—forged condition had somewhat higher rupture strength at 10 and 100 hours than the average for that type of treatment.
- 3. The lack of improvement in properties from a solution treatment was probably related to the forging conditions. It suggests that the finishing conditions during forging were such as to solution—treat effectively both discs and the subsequent solution treatment of one of the

discs did not have an appreciable added effect. Other forging conditions could result in quite different comparative results.

- 4. Hot-cold-working the turbosupercharger discs developed strength properties at 1200° F at the high end of the range of properties possible for this alloy. At 1350° F no beneficial effect was obtained from hot-cold-work. Rupture test ductility of the hot-cold-worked material was very low at both 1200° and 1350° F.
- 5. The two discs showed fair uniformity of properties. Erratic rupture test times at 1200° F were probably due in part to sample location and in part to an inherent erratic characteristic of hot—cold—worked material with low rupture deformation.
- 6. The properties of bar stock of 19-9DL were reproduced quite well in the turbosupercharger discs.

University of Michigan
Ann Arbor, Mich., May 26, 1947

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- 1. Freeman, J. W., Reynolds, E. E., and White, A. E.: A Metallurgical Investigation of a Large Forged Disc of 19-9DL Alloy. NACA ACR No. 5C10, 1945.
- 2. Fonda, L. B.: 19-9DL Type B and C Supercharger Wheels. Data Folder No. 74229, General Electric Co., Sept. 18, 1944.
- 3. Freeman, J. W., Reynolds, E. E., and White, A. E.: A Metallurgical Investigation of Two Contour—Forged Gas—Turbine Discs of 19—9DL Alloy. NACA TN No. 1532, 1948.
- 4. Freeman, J. W., Reynolds, E. E., Frey, D. N., and White, A. E.: Properties of 19—9DL Alloy Bar Stock at 1200° F. NACA TN No. 1758, 1948.

TABLE I

RUPTURE TEST CHARACTERISTICS AT 1200° AND 1350° F

OF TURBOSUPERCHARGER DISCS OF 19—9DL ALLOY

[All specimens were radial near the rim]

Disc Test temperature (Pr) Stress (ps1) Cr) Cr)			1			1	
(Forged; hot-cold-worked) 50,000 289 1 1 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2	Disc	temperature			time	in 1 in.	of area
Solution	(Forged; hot-cold-		50 45 40	,000	141 289 282	1.5 1 1	3.7 1.2 1.2
22,500 152 2 3.7	(Forged; solution—treated; hot—cold—		50,	,000	212 504	3.5	5.1
25,000 62 2 3.7 3.1 17,000 348 2 2.3 2.3	ZD1952	1350	22,	500	152 235	2	3.7 4.0
Disc Test temperature (°F) 10 hr 100 hr 1000 hr	ZD1957	1350	25, 20,	,000	62 172	2 4	3.7 3.1
Disc Test temperature (OF) 10 hr 100 hr 1000 hr				ture s	trength		
ZD1952 1200 a58,000 52,000 37,000 ZD1957 1200 a58,000 52,000 37,000 ZD1952 1350 24,000 13,000 ZD1957 1350 24,000 13,000 Rupture ductility Disc Test temperature Estimated elongation (percent) to rupture in to rupture in	Disc	temperature				psi) for ruptur	e in -
ZD1957 1200 858,000 52,000 37,000 ZD1952 1350 24,000 13,000 ZD1957 1350 24,000 13,000 Rupture ductility Test temperature Estimated elongation (percent) to rupture in to rupture in]	10 hr	100 hr	1000 hr
Disc Test Estimated elongation (percent) to rupture in -	ZD1957 ZD1952	ZD1957 ZD1952 1350		a _e	37,000		
Disc temperature to rupture in -			Rupt	ture di	actility		
(°F) 10 hr 100 hr 1000 hr	Disc	temperature					percent)
		(°F)		1	0 hr	100 hr	1000 hr
ZD1952 1200 5 2 2 ZD1957 1200 3 3 2 ZD1952 1350 - 2 1 ZD1957 1350 - 3 1	ZD1957 ZD1952	1200 1350			5 3	2 3 2 3	2

TABLE II

DATA ON STRESS AND TIME FOR TOTAL DEFORMATION AT 1200° F

FOR TURBOSUPERCHARGER DISCS OF 19—9DL ALLOY

7			Time (h	r) for total	deformations	of -		tion to third— age creep (a)	Creep rate
Disc		(percent)	0.1 percent	0.2 percent	0.5 percent	1 percent	Time (hr)	Deformation (percent)	(percent/hr)
ZD1952	15,000 20,000 37,500 40,000 45,000 50,000 60,000	0.0725 .1005 c.19 c.20 c.23	38	1170 	 75 8 	580 40 1	760	1.1	b .000029 b .000053 d .0003 d .0010 d .0027
ZD1957	15,000 20,000 35,000 40,000 50,000 55,000	.0728 .1090 °.17 °.20 °.27	325	1060	190 20 	810 430 35	1400	1.5	b.000047 d.0005 d.0006 d.0022

^aMost of the rupture tests showed no apparent evidence of third—stage creep prior to fracture.



bCreep rate at 1000 hr for creep tests.

CInitial deformations for rupture tests estimated from stress-strain curves from tensile tests at 1200° F.

dMinimum creep rate for rupture tests.

TIME-DEFORMATION STRENGTHS AT 1200° F OF TWO TURBOSUPERCHARGER DISCS AND A GAS-TURBINE DISC OF 19-9DL ALLOY

TABLE III

Type forging	Total deformation		(psi) to cause t deformation in -	otal
	(percent)	10 hr	100 hr	1000 hr
Turbosupercharger discs ZD1952 and ZD1957 (Approximately 12 in. in diameter.)	0.1 .2 .5 1.0 Transition	17,000 27,000 41,000 48,000	15,000 23,500 36,500 41,000 50,500	13,000 20,000 32,000 35,000 36,500
Turbine disc ¹ (cheese forging) (Approximately 20 in. in diameter.)	.1 .2 .5 1.0 Transition	16,000 24,000 29,000 32,500	14,000 21,000 26,000 29,000 39,000	12,000 17,000 23,500 26,000 33,000

See reference 1.

EFFECT OF CREEP AND RUPTURE TESTING ON THE PHYSICAL PROPERTIES OF
TURBOSUPERCHARGER DISCS OF 19—9DL ALLOY

TABLE IV

	Pr	ior testing co	nditions			Residual room—ter	mperature pro	perties	
Disc	Type test	Temperature (°F)	Stress (psi)	Time (hr)	Tensile strength (psi)	0.02-percent-offset yield strength (psi)	Elongation (percent)	Reduction of area (percent)	Vickers hardness
ZD1952	(a) Creep Rupture Rupture	(a) 1200 1200 1350	(a) 20,000 37,500 15,000	(a) 2600 957 601	^b 133,600 135,000	^b 84,900 71,500	b ₂₅ 16	^b 33 33 	340 320 288
ZD1957	(a) Rupture	(a) 1200 1350	(a) 35,000 17,000	(a) 1475 348	b132,100	^b 83,200	b21 	^b 33	323 306 288

^aOriginal condition.

bGeneral Electric Company data. Average for radial specimens.

TABLE V

RUPTURE STRENGTES OF 17 TURBOSUPERCHARGER DISCS AT 1200° F

Forg	ed; solution—trea	ted; hot-cold-wo	rked		Forged; hot-c	cold-worked			
Disc	R	upture strengths (psi)		Disc	Rupture strengths (psi)				
h.	10 hr	100 hr	1000 hr	2150	10 hr	100 hr	1000 hr		
•			General Electr	ric Company data	fa.				
ZD1957 A-576 A-631 A-711 A-638 A-760 A-761 ZD2265	50,000 61,500 65,500 60,000	47,000 52,500 51,000 55,000 47,500 53,000 56,000 45,000	31,000 39,000 36,000 34,400 37,000 33,800	ZD1952 RCS2 ZC10014 ZD2273 ZD1994 ZD2015 ZD1945 ZD1978 ZD1967	54,100 58,500 53,000 51,800 47,000 56,500 60,300	44,200 48,000 48,000 44,800 44,000 47,000 42,000 50,000 50,800	39,000 25,600 36,300 43,000 40,500 43,000		
Average	59,300	50,900	35,200	Average	54,500	46,500	38,600		
	and the second		University of M	fichigan results		4-1-1-1			
aZD1957	58,000	52,000	37,000	aZD1952	58,000	52,000	37,000		

Rupture strengths, for the two discs covered by this report, based on the combined test data from the University of Michigan and the General Electric Company. (See fig. 4.)



			P	rocessing			Room-temperat				Ruj	ture proper	ties at 120	00° F
m	Heat	Heat	treatm	ent	Hot-cold-work		Yield st		IIIB ON GIBCB)		10	0 hr 100		00 hr
Type forging	number	Tempera-	m.		temperature (°F)	Tensile strength	(nat)		Elongation	Brinell hardness	Strength	Elongation (percent)	Strength	Elongation (percent)
		ture (°F)	Time (hr)	Cooling	(F)	(Psi)		0.2 percent	(percent)	nardness	(psi)	(2)	(psi)	(2)
Disc ZD1952	B10429				1300 to 1350	133,600	84,900		25	250–300	52,000	2	37,000	2
Disc ZD1957	B10429	2100	1	A.C.3	1300 to 1350	132,100	83,200		21	260-300	52,000	3	37,000	2
Disc ⁴ (cheese forging)	B10429	(5)	(5)	(5)		104,700	39,275	54,700	30	185–220	40,000	27	34,000	16
Contour disc6	B11728	2150	2	w.Q.7	1250	119,600	70,500	90,500	26	246-253	47,000	3	38,500	1
Contour disc ⁶ (EXC46)	B11728	2150	2	W.Q.	1650	102,500	39,000	58,000	34	200–223	36,500	20	32,000	14
19-9DL bar stock ⁸	B10429	(9)	(9)	(9)		131,000	70,500	90,000	32	242-252				
S19-9DL bar stock ⁸	B1.0429	2100	1	W.Q.		102,350	26,500	42,250	53	186–189	43,000	20	34,500	50
R19-9DL bar stock ⁸	B10429	(9)	(9)	(9)	1200 (20 percent)	154,200	100,250	125,000	24	321-335	53,000	2	38,000	3

¹All forgings were given a final stress-relief treatment at 1200° F.

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²Estimated.

³A.C., air-cooled. 4See reference 1.

⁵Hot-forged to 1640° F.

⁶See reference 3.

⁷w.Q., water-quenched.

⁸ See reference 4.

⁹Hot-rolled to 1640° F.

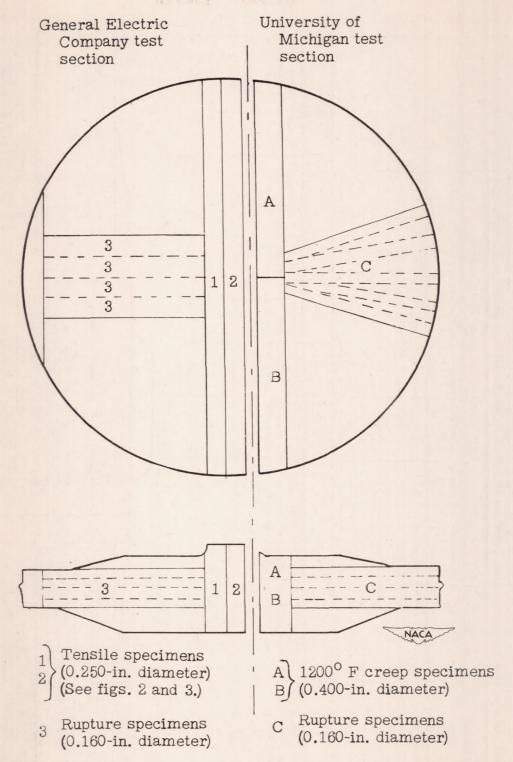


Figure 1.- Location of test coupons in two turbosupercharger discs (ZD1952 and ZD1957) of 19-9DL alloy.

		Unive	rsal-Cy	clops c	ertified	chemic	cal ana	lysis			
C	Mn	Ρ.	S	S Si Cr Ni Mo W		Mo W		Ti	Ср		
0.33	1.14	0.016	0.016 0.015		19.10 9.05		1.35	1.14	0.16	0.35	
Т	est		0.250-	-in. spe	cimens p	pulled a	t test	temper	atures		
tem	tempera— Spec: ture men		str	sile ength psi)	0.02-pe offset stren (ps	yield gth	Elong tion l in. (perc	in	Reduction of area (percent)		
Ro 12 12 15	Room 1 Room 2 1200 3 1200 4 1500 5 1500 6		131 84 82 52	,600 ,600 ,700 ,000 ,650 ,600		000 700	1 1 2	2 8 9 7 1	40 37 40 37 43 45		

Test							0.2	50-in. speci	Slice 2	test tempera	tures
tempera- ture (°F)	Speci- men	Tensile strength (psi)	0.02-percent- offset yield strength (psi)	Elonga- tion in l in. (percent)	Reduction of area (percent)	tempera- ture (°F)	Speci- men	Tensile strength (psi)	0.02-percent- offset yield strength (psi)	Elonga- tion in l in. (percent)	Reduction of area (percent)
Room Room Room 1200 1200 1200	1 26 7 34 58	133,600 132,600 145,000 106,100 86,400 87,200 83,450 82,050	82,050 84,500 92,850 62,050	27 26 22 11 10 16 12	38 27 22 18 31 25 20	Room Room 1200 1200 1500 1500	1 5 2 8 6 7	134,650 136,700 84,400 73,200 56,050 50,300	88,200 89,400	23 19 15 7 11 22	33 14 25 10 20 47

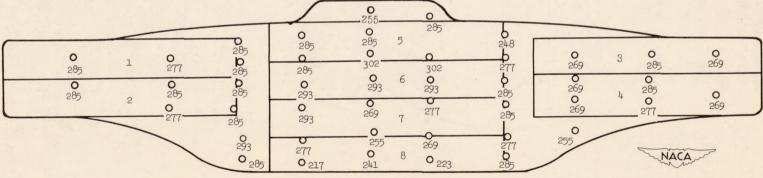


Figure 2.- General Electric Company data on disc ZD1952 of 19-9DL alloy. (Data from reference 2.)

Drawing represents two slices from the center section of the disc, giving 16 short-time test specimens.

		Univ	ersal-C	yclops	certified	chemi	cal ana	lysis			
C	Mn	P	S	Si	Cr	Ni	Мо	W	Ti	Съ	
0.33	1.14	0.016	0.015	0.65	19.10	0.16	0.35				
			Physical treatment by steel improvement lution-treated 2100° F for 1 hr, air-cooled								
Te	st		0.250-	in. spe	cimens pu	illed at	test t	tempera	tures		
temp	tempera— Speci— Tensile strength (psi)				0.02-per offset y streng (ps:	rield gth	Elonge tion: lin. (perce	in	Reduction of area (percent)		
Room 1 136,650 Room 2 137,750 Room 3 133,700 1200 4 87,150 1200 5 86,800 1200 6 89,300 1500 7 48,200 1500 8 54,600 1500 9 54,100		,750 ,700 ,150 ,800 ,300 ,200 ,600	85,2 85,1 87,5	100	28 21 11 11 15 32 21 21	77 + + + + + + + + + + + + + + + + + +	31 34 23 37 33 32 53 37 42				

			Slice 1				Slice 2						
Test	0.25	0-in. speci	imens pulled at	test tempera	tures	Test	0.25	50-in. spec	imens pulled at	test tempera	tures		
tempera- ture (°F)	Speci- men	Tensile strength (psi)	0.02-percent- offset yield strength (psi)	Elonga- tion in l in. (percent)	Reduction of area (percent)	tempera- ture (°F)	Speci- men	Tensile strength (psi)	0.02-percent- offset yield strength (ps1)	Elonga- tion in l in. (percent)	Reduction of area (percent		
Room Room Room 1200 1200 1200	1 2 6 8 3 4 5 7	133,650 130,550 136,750 115,300 109,750 88,200 83,400 83,500	81,850 84,500 84,500 71,200	23 19 18 17 15 12 15	35 35 28 33 31 33 29	Room 1200 1200 1500 1500 Room 1500 1500	6 38 1 2 4 5 7	134,650 86,150 83,700 50,600 52,450 130,600 48,475 50,700	82,000	22 14 5 31 15 20 26 24	25 35 9 64 29 29 54 35		

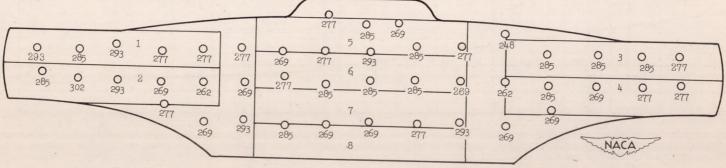


Figure 3.- General Electric Company data on disc ZD1957 of 19-9DL alloy. (Data from reference 2.)

Drawing represents two slices from the center section of the disc, giving 16 short-time test specimens.

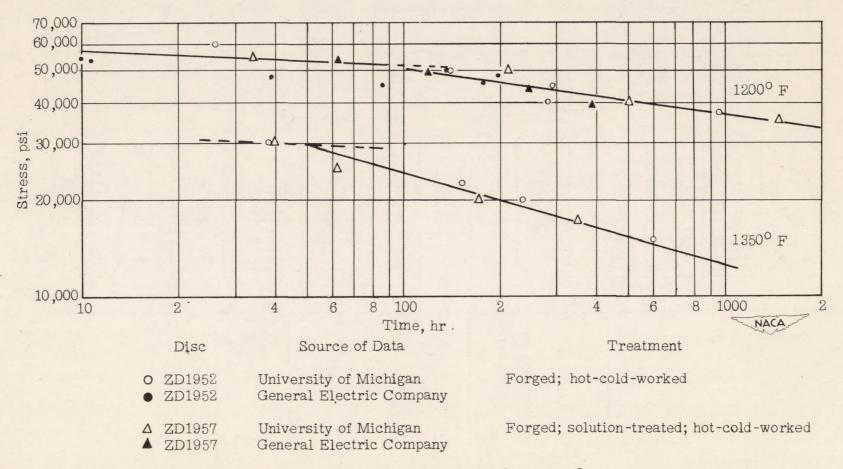


Figure 4.- Curves of stress against rupture time at 1200° and 1350° F for turbosupercharger discs of 19-9DL alloy.

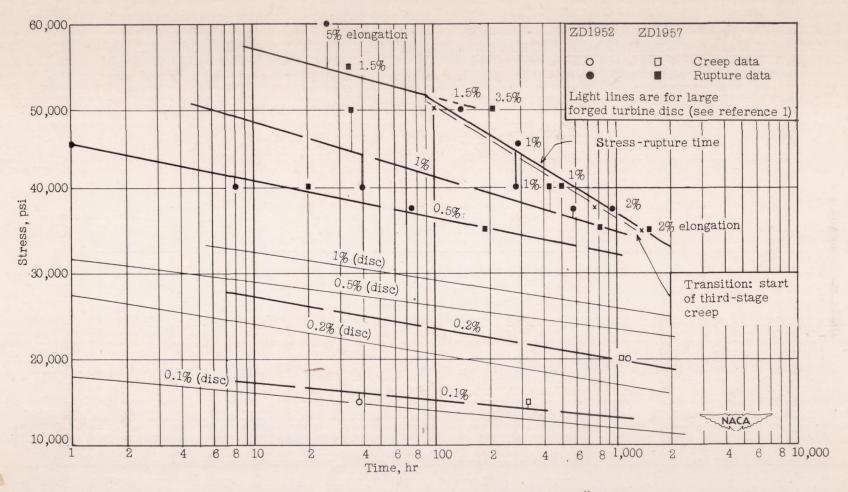
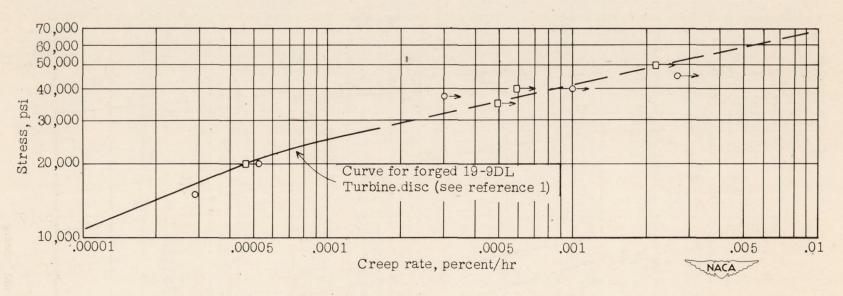


Figure 5.- Curves of stress against time for total deformation at 1200° F for two turbosupercharger discs and a turbine disc of 19-9DL alloy.





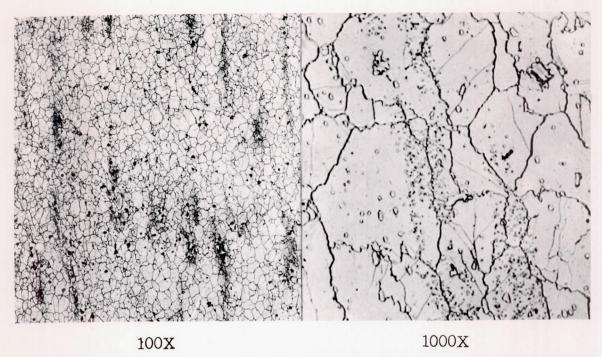
Disc Treatment

O ZD1952 Forged; hot-cold-worked

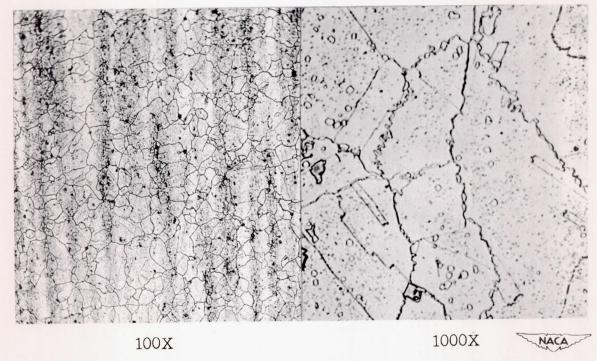
D ZD1957 Forged; solution-treated; hot-cold-worked

→ Test entered third-stage creep

Figure 6.- Curve of stress against creep rate at 1200° F for two turbosupercharger discs and a turbine disc of 19-9DL alloy. All data above 25,000 psi from rupture tests.



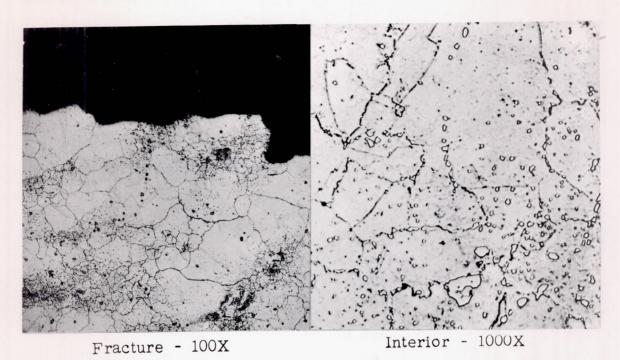
(a) Disc ZD1952; radial section near rim of disc.



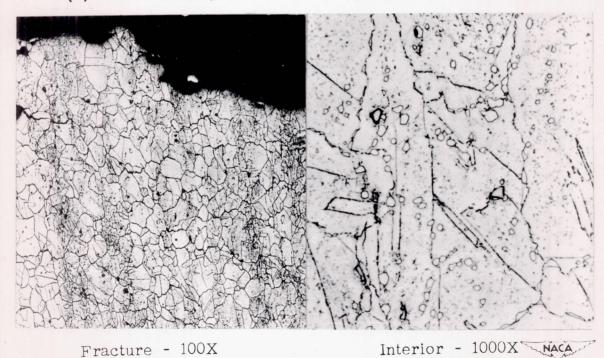
(b) Disc ZD1957; radial section near rim of disc.

Figure 7.- Original microstructures of turbosupercharger discs of 19-9DL alloy. Electrolytic chromic acid etch.



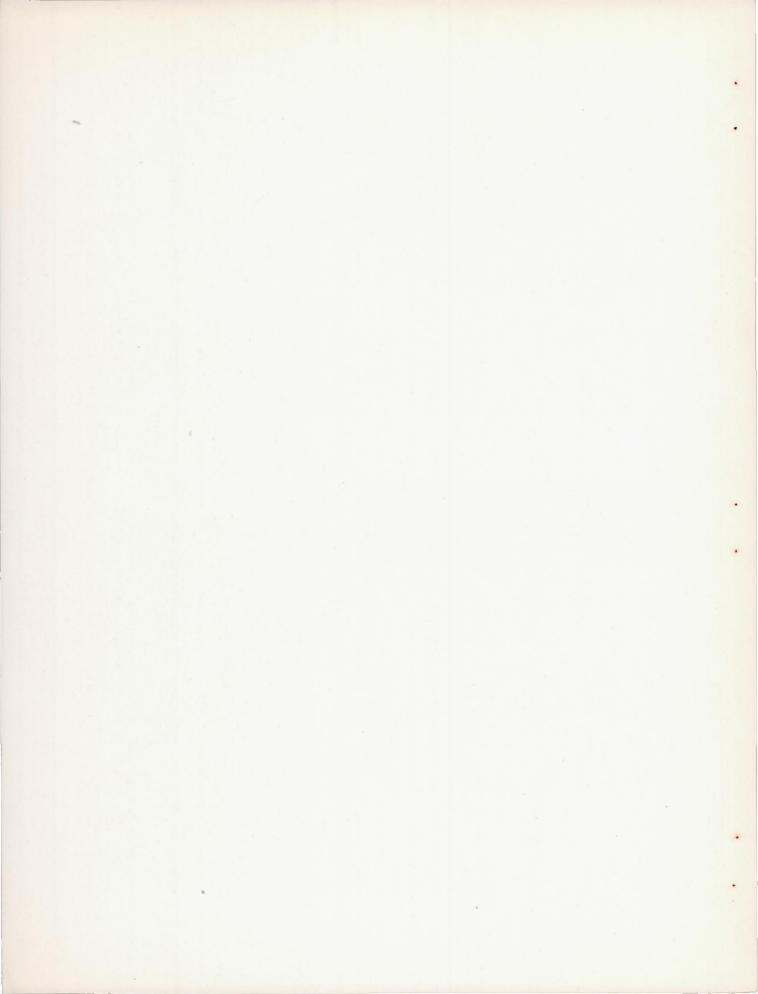


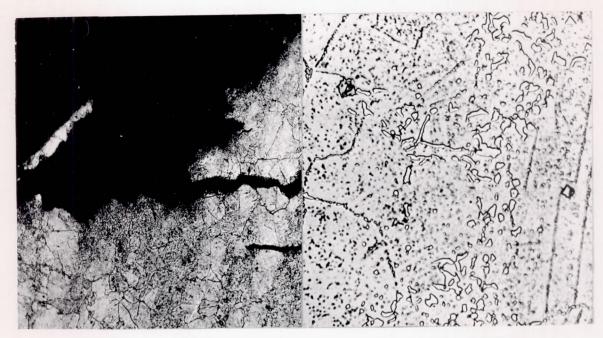
(a) Disc ZD1952; 957 hours for rupture under 37,500 psi.



(b) Disc ZD1957; 1457 hours for rupture under 35,000 psi.

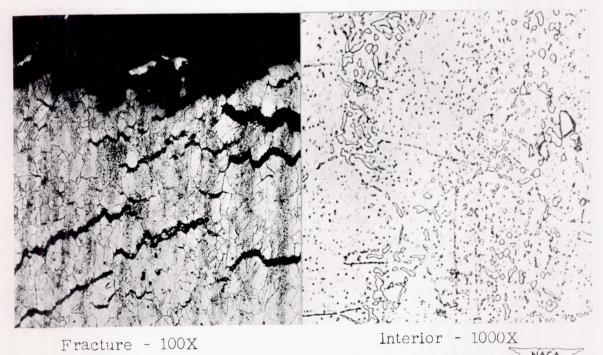
Figure 8.- Microstructures of 1200° F rupture specimens of turbosupercharger discs of 19-9DL alloy. Electrolytic chromic acid etch.





Fracture - 100X Interior - 1000X

(a) Disc ZD1952; 601 hours for rupture under 15,000 psi.



(b) Disc ZD1957; 348 hours for rupture under 17,000 psi.

Figure 9.- Microstructures of 1350° F rupture specimens of turbosupercharger discs of 19-9DL alloy. Electrolytic chromic acid etch.